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SPECIFICATION

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[Method and Apparatus for the Suppression of Pinning in Stereoscopic Display Systems]

Background of Invention

[0001] References Cited

[0002] Vision Research, Vol. 14, no.10, p. 975-82 1974

[0003] Vision Research, Vol. 28, no.4, p. 555-62, 1988

[0004] Neural Networks, Vol. 6, no.4, p.463-83, 1993

Summary of Invention

[0005] The present invention relates to the augmentation of stereoscopic display systems to suppress undesired visual artifacts.

[0006] Stereoscopic image display systems rely on the presentation of slightly different views of a scene to each eye of the viewer. Objects within these separate images are laterally displaced such that each eye sees the same object at somewhat different locations. The discrepancy between perceived location creates a condition known as retinal disparity. The human visual system infers depth by means of this discrepancy and if all such objects within the field of view exhibit consistent stereoscopic cues, the observer perceives a sense of depth and thus a stereoscopic illusion. A variety of stereoscopic display systems have been described in the patent literature.

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[0007] The human visual system relies on a variety of visual cues as it determines depth from the visual images it sees. Depth can be perceived by means of relative motion, relative size, increased detail in objects closer to the viewer, etc. It is well known that some depth cues are more powerful than others. For example, persons with monocular vision can still perceived depth by means of relative motion and by means of observing some objects to obscure others in the field of view. Those objects that

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obscure others are interpreted as being closer than those objects they obscure, for example.

[0008] Human vision relies on a complex and little understood process commonly known as "scene interpretation" as it brings order to visual perception. Such processes include segmentation, color perception, edge detection, etc. If a viewer is presented with conflicting visual cues the normal human response is to restart the process of "scene interpretation" to determine if a more plausible interpretation of the visual field can be made.

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[0009] Consistency of visual cues is extremely important in the creation of stereoscopic imaging. If conflicts occur the sensation of depth is lost and the viewer perceives double vision. The stereoscopically encoded objects are no longer fused so as to be interpreted to be located at various points in space, but are seen as two distinct views that is confusing and uncomfortable for the viewer.

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[0010a] The spatial position of a stereoscopic object is determined by the lateral displacement of that object as seen by each eye. If the right eye and left eye views are superimposed, the perceived location of the object is determined by the relative shift in position. If, for example, there is no shift and if the two views of the object appear at the same location, the object will be perceived as appearing at the surface of the display screen. Such objects are said to have "zero parallax". If an object as seen by the right eye is displaced to the left of the position of the same object as seen by the left eye, the object appears to be floating in front of the display surface and is said to have "negative parallax". Conversely, if an object seen with the right eye is displaced to the right of the position of the same object as seen by the left eye, the object appears to be positioned behind the display surface and is said to have "positive parallax".

[0010b] The movement of stereoscopic objects on a stereoscopic display so that they are clipped by the edge of the display causes a common problem encountered in stereoscopic images. The clipped object is interpreted as being partially occluded by the edge or border of the display. Objects with negative parallax, perceived to be floating in front of the display will create an occlusion conflict when they begin to disappear "behind" the margin of the displayed stereoscopic image. These objects are "occluded" by a visual percept (the margin of the display surface) that has previously been interpreted as behind the stereoscopic object. Occlusion is a more powerful stereoscopic visual cue than is retinal disparity. When these objects begin to intersect the border of the stereoscopic display a conflict in visual cues is perceived causing a loss of the illusion of stereoscopic depth. The region in which the illusion of depth is lost is localized to those border regions in which a conflicts between occlusion and negative parallax occur. Wherever this conflict occurs we shall within the context of this

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patent refer to the image as being "pinned". The conflict will be termed "stereoscopic pinning" and the terms "pinned", "pinning" and "anti-pinning" will be used.

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[0011] The condition that has been described in these teachings as stereoscopic pinning can be controlled when creating stereoscopic movies by insuring that objects perceived as in front of the surface of the display (which is known as the zero parallax plane) are never moved off screen until they have receded to a position that is interpreted as behind the edge of the screen. Since the movie is carefully shot, pinning can be avoided by careful attention to the placement and movement of actors and objects within the scene.

[0012] Accordingly, several objects and advantages of this invention over existing methods and the teaching of the prior art include the object to provide means for suppressing the set of conditions that have been defined in these teachings to cause stereoscopic pinning during the presentation of stereoscopic images, videos, motion pictures and computer generated and or presented stereoscopic material.

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Brief Description of Drawings

[0013] Figure 1 depicts the spectral sensitivities of the three color sensing cones in the retinal mosaic. These are commonly termed Short, Medium and Long Wavelength Sensor and are abbreviated as SWS, MWS and LWS. Label 102 depicts the Long wavelength cone sensitivity curve. Label 104 designates the Medium wavelength cone sensitivity curve. Label 106 designates the Short wavelength cone sensitivity curve. Each cone sensor type can recelved a broad spectrum of light. Color is derived by comparing the signaling strength from neighboring cones. The Medium and Long Wavelength cone sensitivities overlap broadly whereas the Short Wavelength Sensor type cone has a narrow spectral range that does not broadly overlap the sensitivities of the MWS and LWS cones. As depicted in Figure 1, light whose frequency is at or near 450 nanometers is primarily sensed by the SWS cones.

[0014] Figure 2 depicts the relative distribution of short, medium and long wavelength sensing cones. The figure consists of two micrographs of the same region of the retinal mosaic. The, labeled 202 includes the macular pigment. The second, labeled 204 depicts the same region without the macular pigment. The cones are more clearly seen in the region labeled 204. The Long wavelength cones are depicted by label 206. Label 208 depicts the Medium wavelength cones whereas label 210 designates the Short wavelength cones. There are approximately sixteen times more medium and long wavelength cones than short wavelength cones as is indicated in this micrograph.

[0015] Figure 3 depicts the central region of the fovea: the region of highest visual acuity. The area designed as 302 depicts the fovea region whereas label 304 indicates

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the central fovea. In this region of the retina the cone cells are smaller and more tightly packed than in the periphery of the retina. Moreover there are no short wavelength sensors in the central fovea.

[0016] Figure 4 shows a stylized representation of the apparatus described in this patent. Element 402 is the stereoscopic display device including border element 404 and display element 406. The viewer's right and left eyes are depicted as elements 408 and 410, respectively. The anti-pinning border is defined by the region bounded by elements 412 and 414.

Detailed Description

[0017] Although the following detailed description contains many specifics for the purposes of illustration, anyone of ordinary skill in the art will appreciate that many variations and alterations to the following details are within the scope of the invention. Accordingly, the following preferred embodiment of the invention is set forth without any loss of generality to, and without imposing limitations upon, the claimed invention.

[0018] The present invention accordingly has an objective to provide a variety of novel means for the creation of apparatus for presentation of stereoscopic material.

[0019] A preferred embodiment of this invention employs a perimeter around the displayed stereoscopic image that serves to provide ambiguous depth cues. Such ambiguity reduces or eliminates a well known stereoscopic artifact that has limited the use of stereoscopic imaging. This artifact will be called "stereoscopic pinning" in the context of these teachings. Stereoscopic pinning occurs only when a stereoscopic object is presented to the viewer so that it will be perceived to be positioned as if floating in front of the display surface. If that object is translated so that it either touches or begins to move off the edge of the display, the visual system observes two conflicting visual cues: an object interpreted as being in front of the display is occluded by the edge of the display (which is perceived as behind the object). Since occlusion is a more powerful visual depth cue than is retinal disparity, the illusion of depth is broken and the viewer no longer perceives a stereoscopic image.

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[0020] The problem of stereoscopic pinning can occur in all real time stereoscopic imaging systems. Those skilled in the art of creating stereoscopic content knowingly create stereoscopic content such that forward objects, those with negative parallax never intersect the edge of the display. By doing so they prevent stereoscopic pinning from occurring.

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[0021] The apparatus described in this invention and shown in Figure 4 employs a luminous blue border along the periphery of the displayed image. The use of blue light is intentional because of a variety of factors related to the human visual system.

[0022] It is well known to those skilled in human vision that the lens of the human eye is a simple lens that is achromatic. That is, the lens focuses light of different wavelengths (colors) at various position in space. Light of deep blue color is always focused at a point that is substantially in front of the retina and is thus always perceived as out of focus. Moreover, blue light is primarily sensed by one of three color photoreceptor cells of the retina which are called SWS (Short Wavelength Sensor) or S cones. The region of the human retina which has the highest spatial acuity is located in a region known as the fovea region of the retina. It is well known that S cones are not present in the central region of the fovea. S cones begin to occur in the peripheral region of the fovea and are significantly less numerous, as is shown in Figure 2, than the other two types of color receptive cells (the MWS or M cones and the LWS or L cones). Various studies report that there are as few as one sixteenth as many S cones in the retina as other color sensors. The perception of blue light and in particular the use of a luminous blue border around the stereoscopic image provides ambiguous visual depth cues that inhibit and reduce the problem of stereoscopic pinning. Ideally, the luminous blue border should generate light that is only perceived by the S cone sensors (a wavelength of approximately 450 nanometers or shorter).

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[0023] The illusion of depth created by stereoscopic imaging is dependent on presenting slightly different images to each eye. Elements within each image are displaced laterally in a manner that is proportional to their perceived distance to the viewer. It is clear that the border of the stereoscopic displayed image can become a factor that can inhibit the perception of depth even though consistent stereoscopic cues (retinal disparity) are provided throughout the displayed image.

[0024] Moreover, the luminous deep blue border along the edge of the display surface can be constructed so that the edge of the displayed image merges into the bordering region such that the intensity of the edge of the displayed image is subtly merged to deep blue, thus decreasing the discontinuity between the border of the displayed stereoscopic image and the image itself.

[0025] The apparatus now disclosed and described can be further augmented to enhance the stereoscopic viewing experience by employing a luminous blue perimeter bounding the edge of the stereoscopic display area as shown in Figure 4.

[0026] It is well known within the art that the human visual system employs a variety of visual data in order to perceive a sense of depth. These include relative size, relative motion, retinal disparity and object occlusion. Object occlusion is a more powerful visual cue than is retinal disparity.

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[0027] It also well known that stereoscopic objects made to appear as if in front of the display surface can cause a conflict in visual cues if said object(s) move to or off the field of view. The object is seen to disappeared behind the edge of the display and thus be occluded by an object that was initially perceived as behind said object. When this occurs the perception of depth is lost. The two displayed images are no longer fused in the mind to create the stereoscopic illusion of depth and the displayed images are not fused and now appear as two displayed images. The illusion of depth is lost. "Stereoscopic pinning" is a term defined within these teachings that is used to refer to the creation of this condition in stereoscopic display systems.

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[0028] It has been discovered that stereoscopic pinning can be suppressed and/or eliminated by means of providing a luminous deep blue border around the periphery of the stereoscopic display area.

[0029] Some aspects of human vision, although studied, are not well understood. But a rational argument can be made as to why this effect occurs. For example, the lens of the eye is a simple lens subject to chromatic distortion. Different wavelengths (colors) of light come to focus at different distances from the lens and the retina. Some colors (e.g. red) come to focus at a position that is somewhat behind the surface of the retina. Conversely, other colors, such as blue (short wavelength light) come to focus substantially in front of the retina. The human visual system is not capable of focusing blue light onto the retina of the eye.

[0030] The perception of color in the human visual system is not well understood. A number of retinal light sensing cells (cones and rods) have been identified. The frequency response and spatial distribution of these cells has been studied in great detail. There are three types of cone or color sensing cells within the eye which are typically called Long Wavelength, Medium Wavelength and Short Wavelength Sensors (L, M and S cones). As shown in figure 1, the frequency response of the L and M cones is broad whereas the S cones have a narrow frequency response. And although there is considerable overlap in the sensitivities of the L and M cones there is relatively little such overlap in the frequency response of the S cones.

[0031] It is well known that there are no S cones in the most sensitive region of the retina which is called the fovea. Whereas most regions of the retina consist of a mixture of rod and cone sensing cells, the fovea only contains cone type cells and only those which are of the L and M types. S type cones are only detected in the periphery of the fovea region and their spatial distribution is much lower than either the L or M cones. It is estimated that there are less than one sixteenth as many S cones as either L or M cones in the retina.

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[0032] Since short wavelength sensing cells (S-cones) do not occur in the central region of the fovea, it is well known that it is visually impossible to attain focus on an object emitting only shortwave length (e.g. blue only) light. The elements of the image are defocused by virtue of the achromatic characteristics of the lens of the eye and also by the absence of appropriate sensor cells within the prime focus region of the retina.

[0033] The combination of defocused short wavelength (blue) light and lack of S cones in the area of highest visual acuity results considerably lower spatial sensitivity of the human eye to blue light. Blue objects must be substantially larger in size to be perceived clearly by the eye. These factors appear to make difficult, if not impossible to derive depth information from purely blue elements.

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[0034] A luminous blue border around a stereoscopic image creates a zone of depth ambiguity about the location of the screen on which the stereoscopic image is displayed image. This ambiguity can be employed to suppress and inhibit stereoscopic pinning and is employed for this purpose in this patent.

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[0035] Figure 1 teaches that there is little overlap in spectral response between S- and either L- or M- cones at wavelength at 450 nm or less. As such, the luminous border described should emit light at approximately this or shorter wavelengths.